LEMIC – 27 November 2001

Alignment of the LHC machine and experiments

Part 2) The experiments

C. Lasseur EST-SU-EXP

The general concept …

A tentative global 'survey' error budget

Status in the zones : Atlas , CMS, Alice, LHC-b

The experiments reference at the start of their installation and after …

Information from survey to the experiments

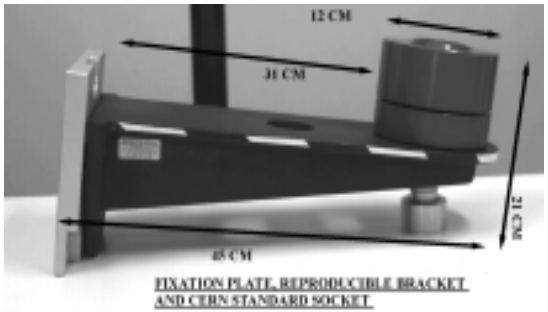
Questions and pending answers …

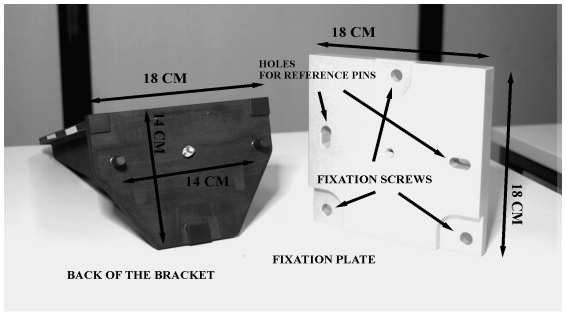
- **Floor movements : status in Atlas**
- **Nominal beam line : status in Atlas**

The general concept …

The geometric network in the cavern is the only permanent external link to the machine geometry of any point in the experiment

- **set up and used at any time when zone is accessible …**
- **performances of survey on the detectors strongly depend on its configuration in the cavern,**
- **surrounding reseau plug-in brackets on walls and on metallic structures (Atlas)**





- **layout adapted to survey works and to the installation sequences … as much as possible**
- **prototypes : stability and reproducibility tested … < 50 microns**

the datum and the control positions of the network are the Survey reference lines …

the external permanent lines linked to the machine geometry via the lateral survey galeries

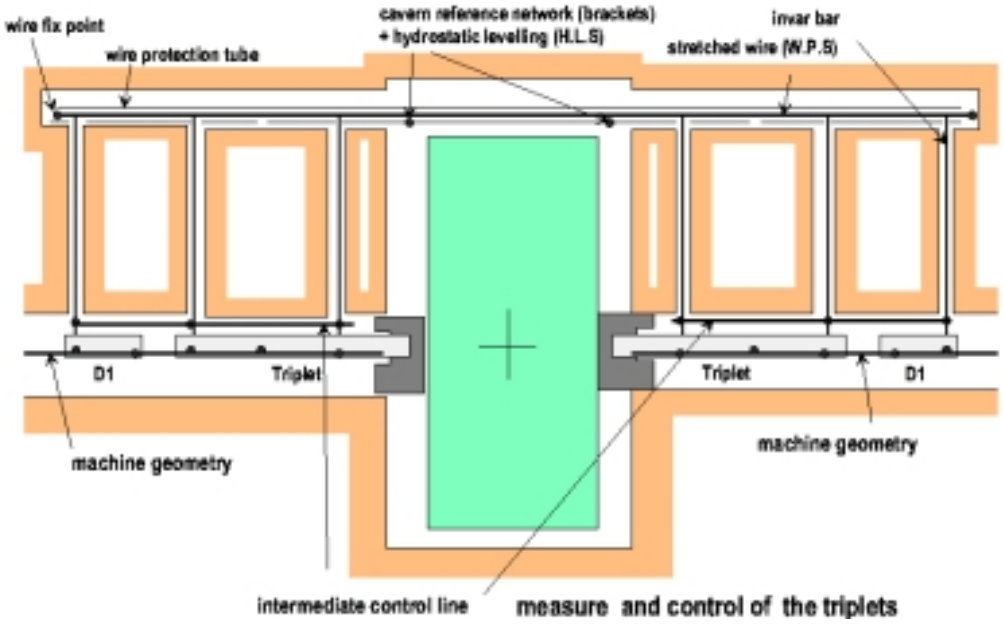
these lines traverse the experimental area in a protection tube – Exp-Integration plus SU-ACC-EXP

STRECHTED WIRE/HYDROSTATIC LINE = REFERENCE LINES INSIDE THE CAVERN

ALSO ALTIMETRIC DEEP REFERENCE RODS IN THE TUNNEL …

regular link measurements are possible w.r.to the machine geometry via the survey galeries,

A tentative global 'survey' error budget (Lemic 97-5, note 22)



- *reference lines / machine geometry …*
  radial 0.1 / 0.2 mm levelling 0.1 / 0.3 mm
- *cavern wire side lines / reference lines …*
  radial 0.2 / 0.4 mm levelling 0.1 / 0.2 mm
  any fiducial mark from the cavern wire side line
- *any other cavern network stat. / cavern wire side …*
  0.5 mm ... 3D XYZ
- *any fiducial mark / any other cavern network stat.*
  0.3 / 0.7 mm …3D XYZ depend on location !

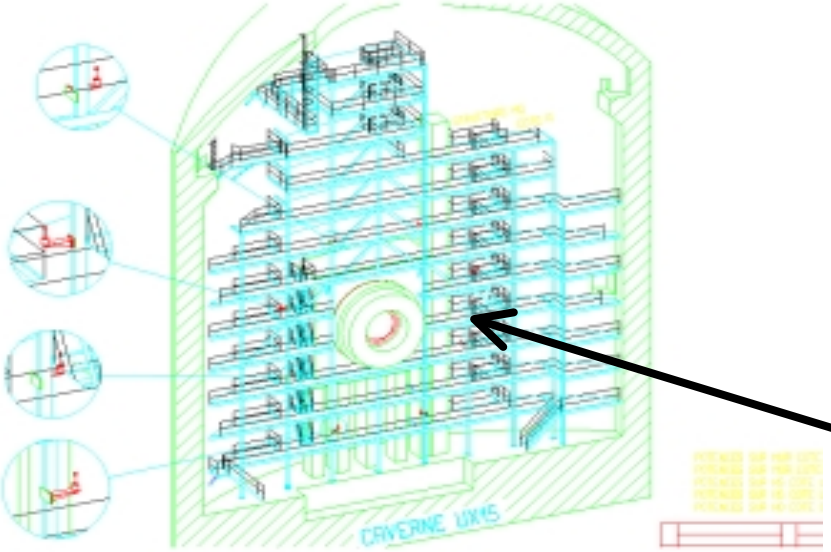
GLOBAL : 0.5 mm to 1.2 mm r.m.s (66.6%) FOR any fiducial mark w.r.to 'machine geometry'

- **'TRUE' UNCERTAINTY' ... when fiducials marks well known and working conditions defined …**
  simulations with correlations, better estimation *of time and staff !!!*

BUT : first configuration NOT reproducible initial accuracy cannot be kept everywhere for ever PLUS …

- **walls shrinkage … ex : LEP UXs ≅1 cm/15 months at beam level, then ≅ 1 mm/year over 3/4 years after …**
- **floor, detectors, structure vertical creeps w.r.to load and time**
  - **ex : LEP exp. : 2. 5 mm Aleph, Delphi barrels completion … then stability < 1 mm w.r.to the machine**
  - **never deep leveling reference in LEP never absolute values, always w.r.to machine smoothing,**

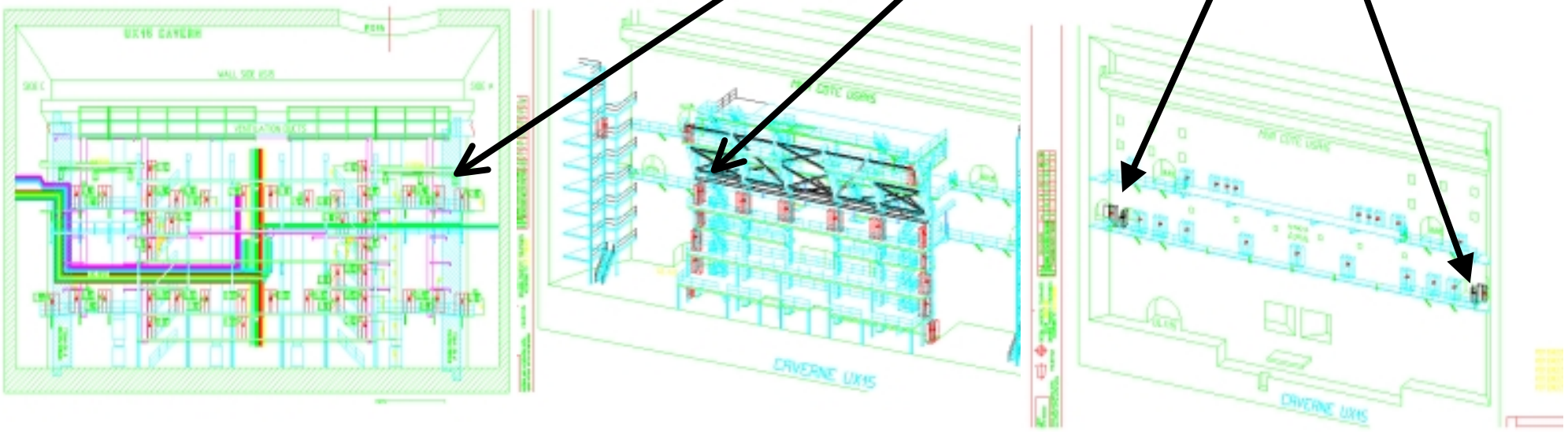
'refreshing' regularly /'machine line' during installation and maintenance … 'permanent' measurements ??



Status in the zones : Atlas … network finalised

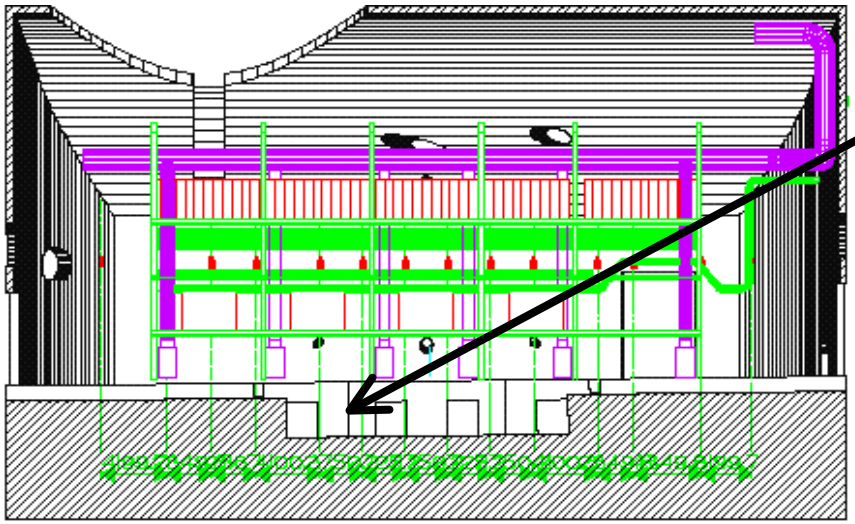
- **today positions … F.Galleazzi / D. Parchet (EST-Atlas Infra)**
- **EDMS - ATLAS : ATFIM 0001 … ATFIM 0012 (Robcad …) in the baseline cavern layout LIKE SERVICES, datum lines (16.35 m) and control positions on USA walls strategic stations …**

HO for barrel toroid, walls and HS for muons, 4 for TAS,



AT LEAST THE STRETCHED WIRE PLUS NETWORK ON HO PLUS WALLS IN MAY/JUNE 2003 … the 9.6 m gangway is needed asap …

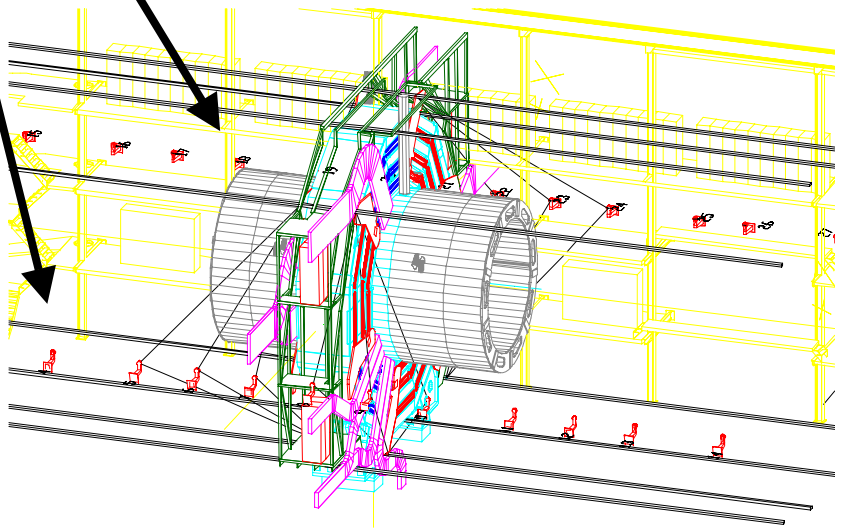
Status in the zones : CMS … basic principles fixed and network under finalisation



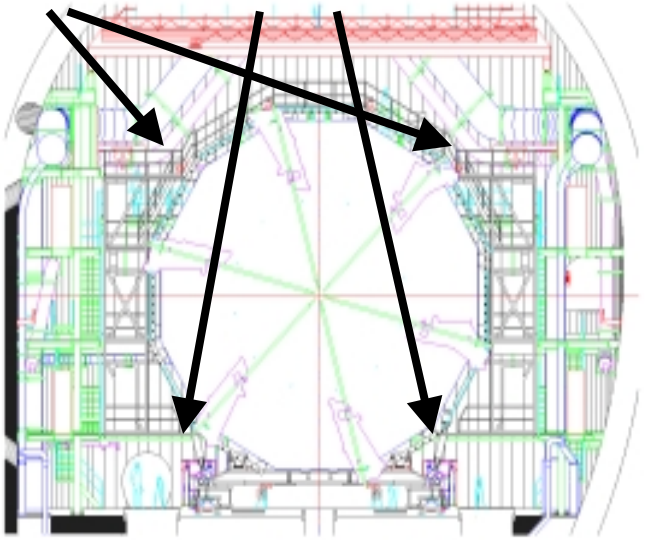
- brackets w.r.to the intervals wheels and endcaps (J.F. Michaud)

- 2 lateral horizontal lines : one linked to the datum lines (11 m)

42 BRACKETS : WALLS AND TYMPANS

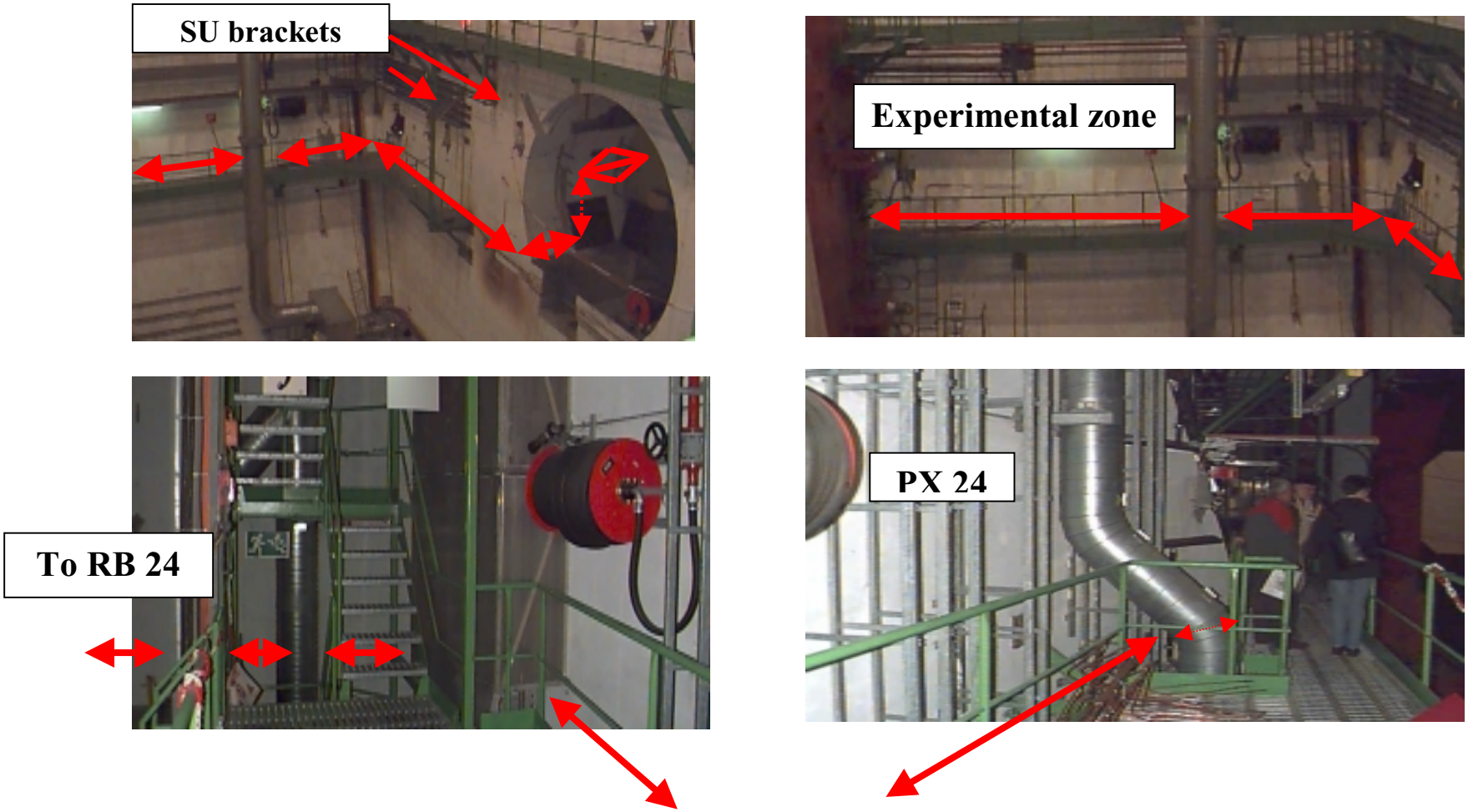


- 4 top and 4 bottom lines : tympans and reserved corridors



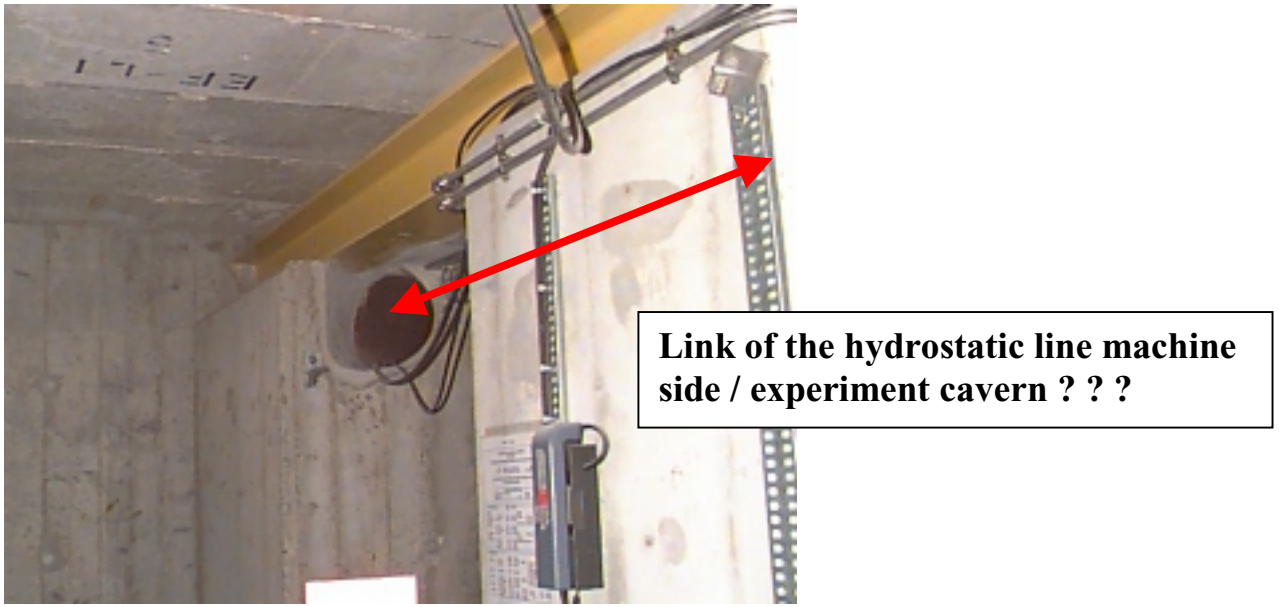
Status in the zones : Alice and LHC-b … no stretched wire … only an hydrostatic line

Alice : some brackets left, network not studied on RB 24 side … still 'stuck' on detectors integration
- link with machine : muon filter on RB 26 side, shielding on RB 24
- preliminary 'view' of the hydrostatic line passage and obstacles (H. Mainaud – Acc. Sector SU)



LHC-b :

- **no brackets left, neither network and detectors integration studied yet**
- **preliminary 'view' of the hydrostatic line passage and obstacles (H. Mainaud – Acc. Sector SU)**
- **using the two oblique tubes above the 'chicanes' ???**



The experiments reference at the start of their installation and after … (Atlas/CMS)

- **the initial geometry is given by the machine : precise marks on floor and plug-in tripods,**
- **… good within +-1 mm w.r.to the theoretical positions of elements,**

- **it will be 'translated' onto the streched wire in the lateral survey galeries via the radial tubes with precise and calibrated rods equipped with capacitive sensors at extremities (0.1 mm) : everything installed asap the cavern is accessible, alternative is an accurate radial distance with a precise distancemeter (0.1 / 0.2 mm),**

- **alternative : auxiliary plug-in tripods in the shielding region (Atlas) alas and asap with direct view towards the cavern**

- **the reference leveling is given by the embedded deep reference rod and transmitted via the radial tubes and galeries via a geometrical leveling (0.2 / 0.3 mm) first - the hydrostatic line may be installed later.**

- **the main brackets are installed and the first network measure is done in the same time, namely :**
  datum brackets … physically and directly linked to the wire and the hydrostatic line,
  control and key positions brackets on walls,

THE FINAL MACHINE ALIGNMENT ('nominal beam position') IS DONE first via the marks on floor and plug-in tripods and also via line for 'smoothing' the machine adjacent elements (LowQuads, TAS,)
no significative gap > 0.5 mm expected of the experiment line/the 'nominal beam position',
'definitive' coordinates w.r.to the 'nominal beam position' and new coordinates of already installed sub-elements will be re-adressed and will be available for the ID detectors and the beam pipe,

the streched wire and the deep reference rod are the unique common references and datum lines for re-measurement and maintenance in experiment and machine adjacent elements.

Information from survey to the experiments … (partly D.Lissauer)

Object envelope definition : under proper load plus as-built ?

Survey can provide additional data to CDD/CAD model or information from industry

- **pre-assembly, on surface or factory, when modular or attached units,**
- **specific geometrical or dimensional parameters available for envelope or placement,**
  - **ex Atlas : pre-assembly tile, LArg vessels and all modules, feet and coils, endcaps toroid**
  - **ex CMS : 5 yoke wheels (3 times), endcaps plates (2 times), HB barrels (2 times), coil**

Relative placement of adjacent elements and global assembly accuracy needed.

Anticipated or suspected movements that experiment would like to keep tracked :

- **floor movements … How ? Permanently ?**
- **deformation on the rails when installing the Atlas Barrel Cal ? How ? Permanently ??**
- **actions to be taken ? Define a 'primary working plane' w.r.to overall movements ??**

Installation Sequences and planned mechanical adjustments during installation …

- **sequences under permanent survey control for immediate actions,**
- **preparatory works, in surface or in the cavern, could be done to help final installation.**

What to be surveyed during maintenance and relevant preparation (accessibility guaranteed).

Final Survey information in conjunction with relative accuracy w.r.to the machine geometry.

An 'ATLAS Placement Specification and Strategy' document is under way …

Questions and pending answers … Floor movements : status in Atlas (D. Lissauer)

First information from H. Rammer (May 97) …

- ***Floor Settlement:*** ***-2 mm from the time the concrete if poured and the time Atlas gets possession of the experimental hall.***

- ***Floor Due to weight: -5.5 mm (Total –7.5 mm) due to the weight of the exp. over ~ 6 months.***

- ***Floor upward lift due to Hydrostatic Pressure:***
  ~ + 1 mm / year due to hydrostatic pressure - up to ~ 20 mm over 20 years.

- ***Floor Modification Under consideration : Mark Hatch***
  - truck movements and the need for "bridges", changes in the trench design.

- ***Review existing calculations and new calculations : Olga Beltramello***
  - ***review of the existing calculation : calculations done with simplifying assumptions … too large of a grid, uniform load on the floor.***

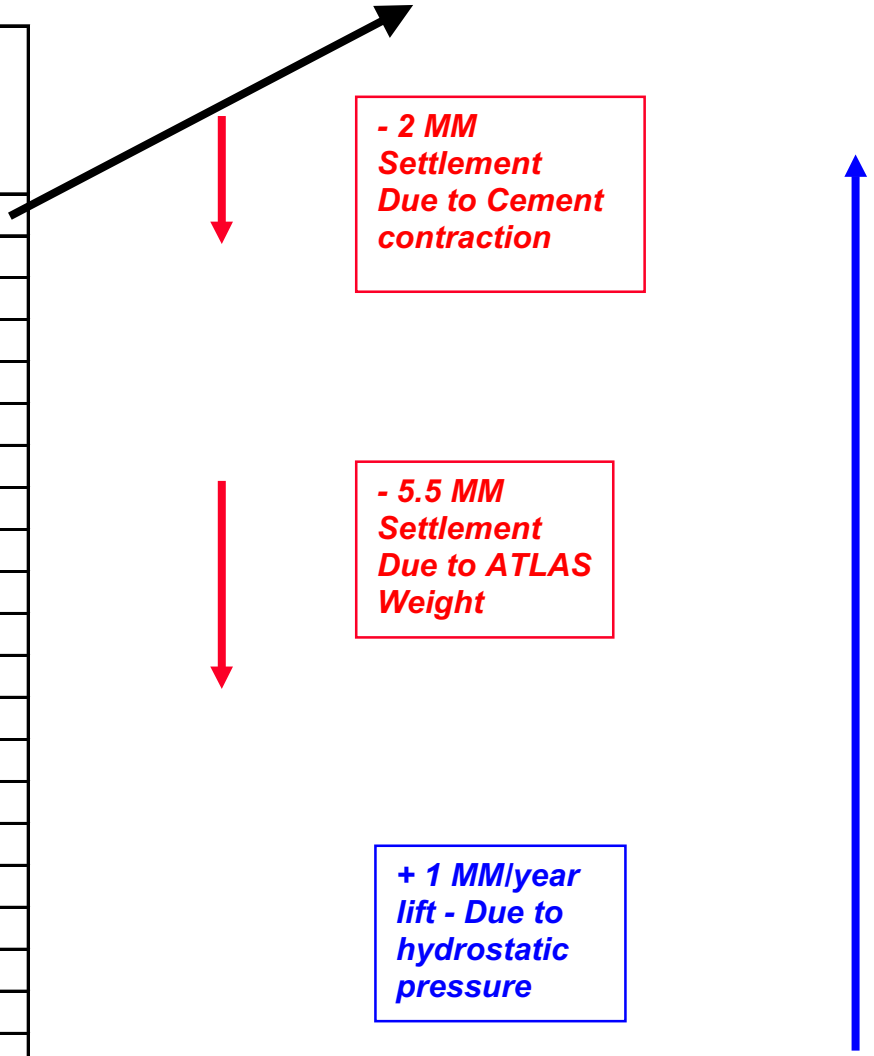
New calculations are underway for the Atlas cavern

Implication of floor and objects mvts in CMS not so much detailed yet …

Floor movements : status in Atlas (D. Lissauer)

u **Summary of the 'pessimistic' prediction for the floor movements : assumption + 3.5 mm**

*Instalation Time**	*Floor Movement (no Lift)*	*Lift 1mm After 1 Year*	*Net floor Move*	*Relative To Nominal*
*Floor installation **	*0.0*	*0.0*	*0.0*	*3.5*
*ATLAS Gets Exp.***	*-2.0*	*0.0*	*-2.0*	*1.5*
Toroid/Feet	*-2.0*	*1.4*	*-0.6*	*2.9*
Rail Installation	*-2.0*	*2.0*	*0.0*	*3.5*
Barrel	*-3.0*	*2.0*	*-1.0*	*2.5*
*EC Cal **	*-4.0*	*2.5*	*-1.5*	*2.0*
ID Instlation	*-6.0*	*3.2*	*-2.8*	*0.7*
*EC Toroid**	*-6.5*	*3.5*	*-3.0*	*0.5*
First Beam	*-7.5*	*4.0*	*-3.5*	*0.0*
1 year	*-7.5*	*5.0*	*-2.5*	*1.0*
2 years	*-7.5*	*6.0*	*-1.5*	*2.0*
3 years	*-7.5*	*7.0*	*-0.5*	*3.0*
4 years	*-7.5*	*8.0*	*0.5*	*4.0*
5 years	*-7.5*	*9.0*	*1.5*	*5.0*
6 years	*-7.5*	*10.0*	*2.5*	*6.0*
7 years	*-7.5*	*11.0*	*3.5*	*7.0*
8 years	*-7.5*	*12.0*	*4.5*	*8.0*
*9 years****	*-7.5*	*13.0*	*5.5*	*9.0*
10 years	*-7.5*	*14.0*	*6.5*	*10.0*
11 years	*-7.5*	*15.0*	*7.5*	*11.0*
12 yeasr	*-7.5*	*16.0*	*8.5*	*12.0*



u Nominal beam line : status in Atlas (D. Lissauer)

From Close orbit calculations the Nominal Beam Line (Geometrical line) and the "actual" beam line might be as much as 3 mm off.

This is probably a conservative number – we are trying to get a better estimate from the machine. (K. Potter et al.)

Beam Adjustments:

- "Immediate": Order of less than 1 mm by changing the magnetic field in the last magnet

- "Short term": Order of 1 mm by adjusting the physical location of the last triplet which is adjustable on jacks

- "Long term": Re-align a string of magnets along the tunnel. Adjustments could be as high as 1 c.m. but much more information and interaction with the machine is needed. (K. Potter et al.)

Ongoing discussions with the Machine, Survey group: K. Potter is our contact for these discussions.

Preliminary answers seem to be not all negative.

- It looks like it might be possible to re-align the machine once every three or four years so that the IP will coincide with the ATLAS IP as long as this change is of the order of ~10-20 mm.